METAALICUS PROJECT

(Mercury Experiment To Assess Atmospheric Loading in Canada and the US)

Relating Mercury Deposition to Methylmercury Levels in Fish

Presentation by

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EPRI

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USGS

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Public and Private Sector Participation

- Fisheries and Oceans Canada
- USGS
- EPRI
- University of Wisconsin/WDNR
- US EPA
- US DOE
- Academy of Natural Sciences, MD
- Minnesota Pollution Control Agency
- U. Toronto, U. Quebec, Trent U., U. Alberta
- NSERC
- Environment Canada
- Tetra Tech Inc.
- Swedish IVL institute

Principal Investigators:

The Freshwater Institute: Ken Beaty, Paul Blanchfield, Drew Bodaly, Carol Kelly, Mike Paterson, Cheryl Podemski, John Rudd, Michael Turner

The Academy of Natural Sciences: Cindy Gilmour

Tetra Tech: Reed Harris

Trent Univ.: Holger Hintelmann

USGS: Dave Krabbenhoft

US DOE: Steve Lindberg

U. Alberta: Vince St. Louis

U. Maryland: Rob Mason, Andrew Heyes

U. Montreal: Marc Amyot

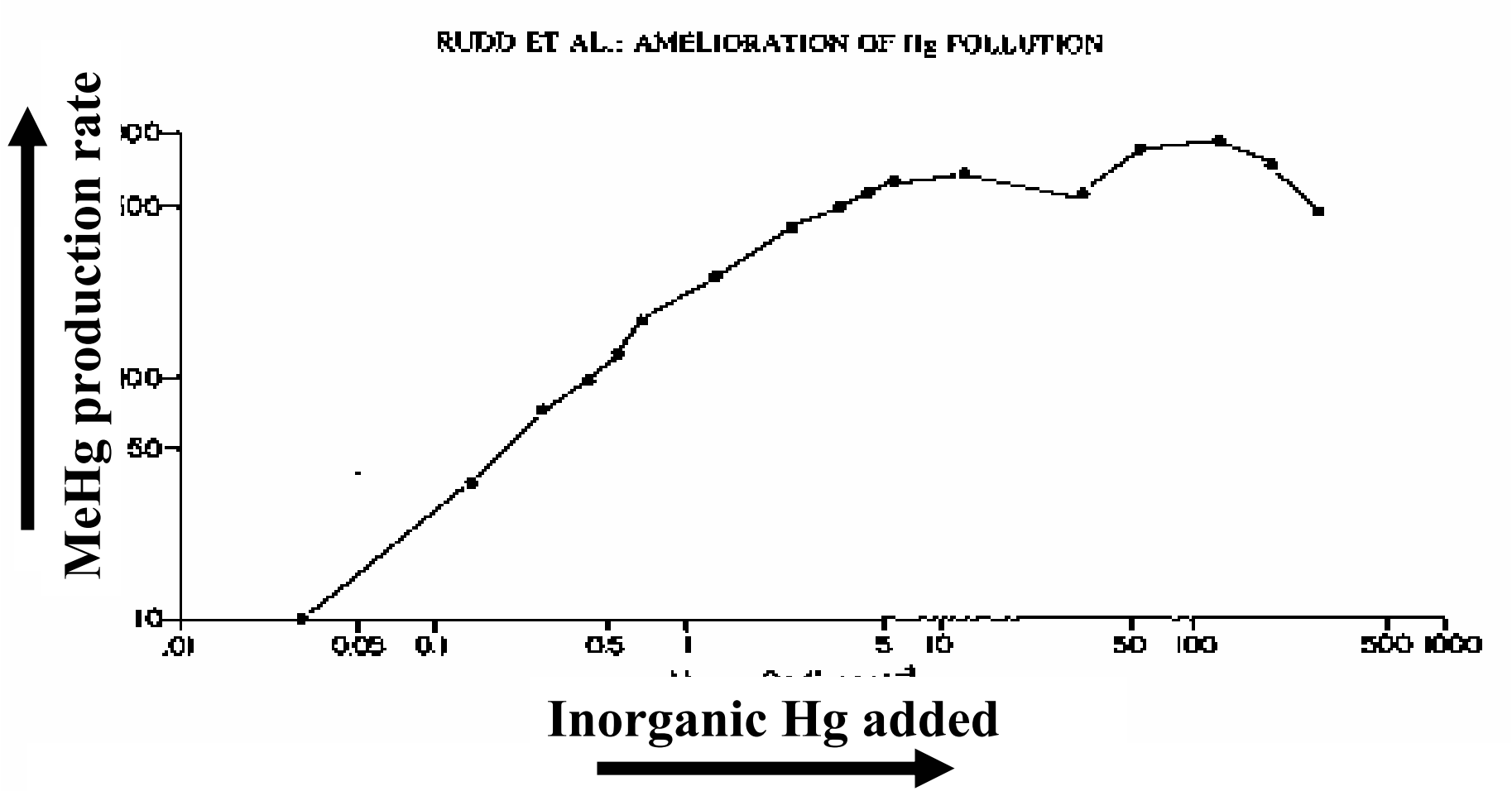
U. Toronto: Brian Branfireun

U. Wisconsin: Jim Hurley, Chris Babiarz

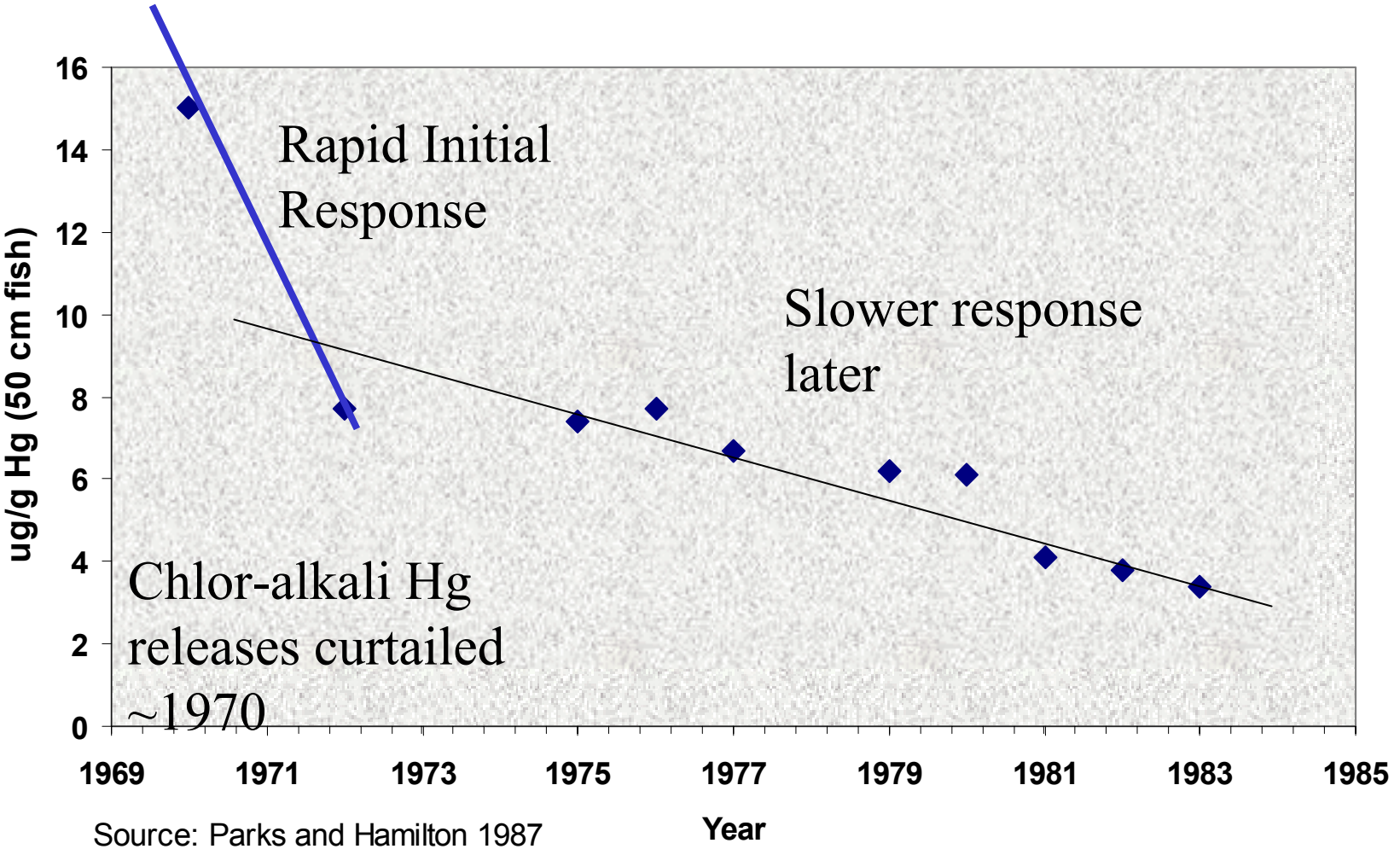
Fundamental Questions to be addressed by METAALICUS

- What is the relationship between the amount of Hg in atmospheric deposition and the amount of methylmercury in fish?
- How quickly will the fish Hg levels respond to a change/reduction in mercury deposition?
- How will environmental factors affect the magnitude and timing of the response?

We have limited laboratory and mesocosm data, but what would happen in the real world?

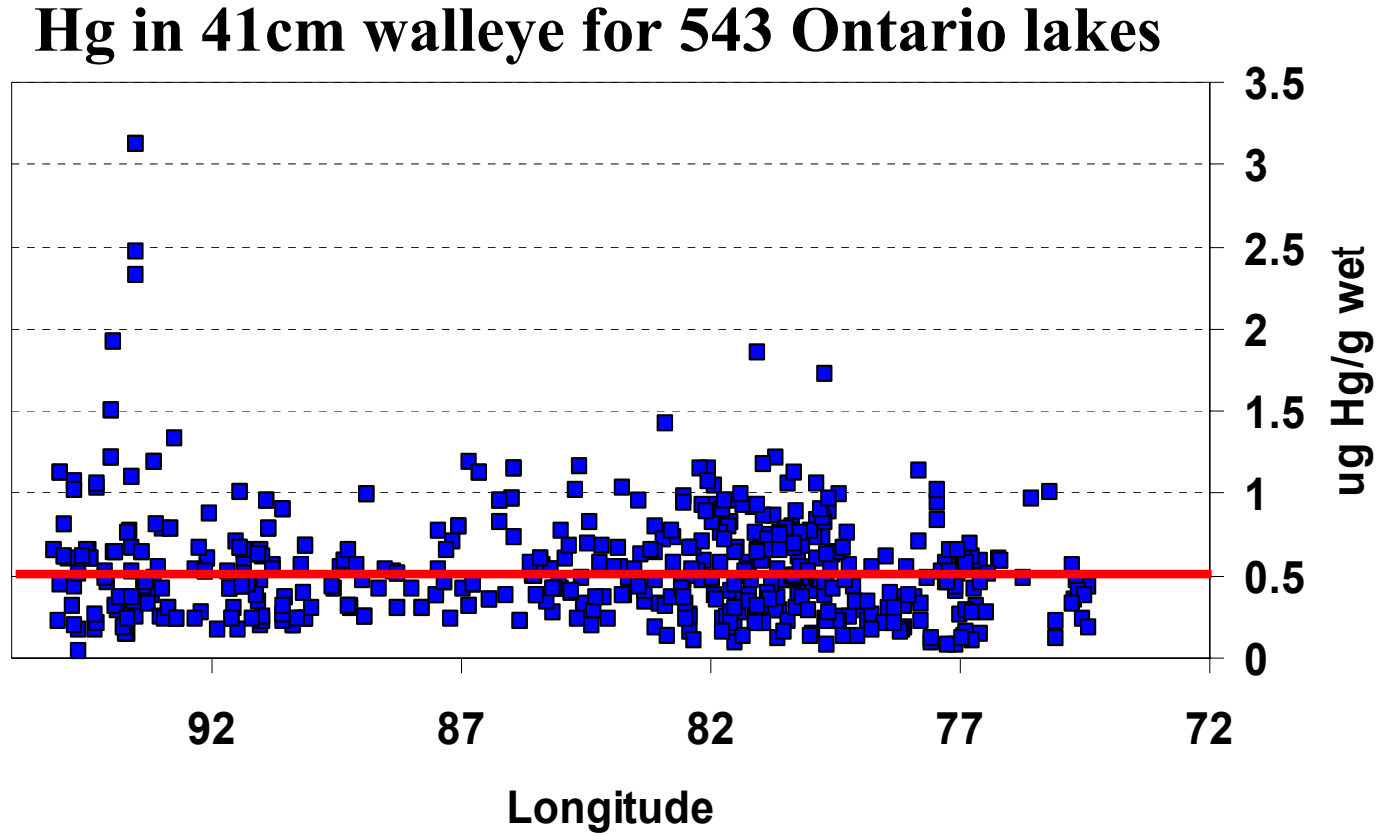


Observed Walleye Mercury Concentrations for Clay Lake, Ontario (1970-1983)



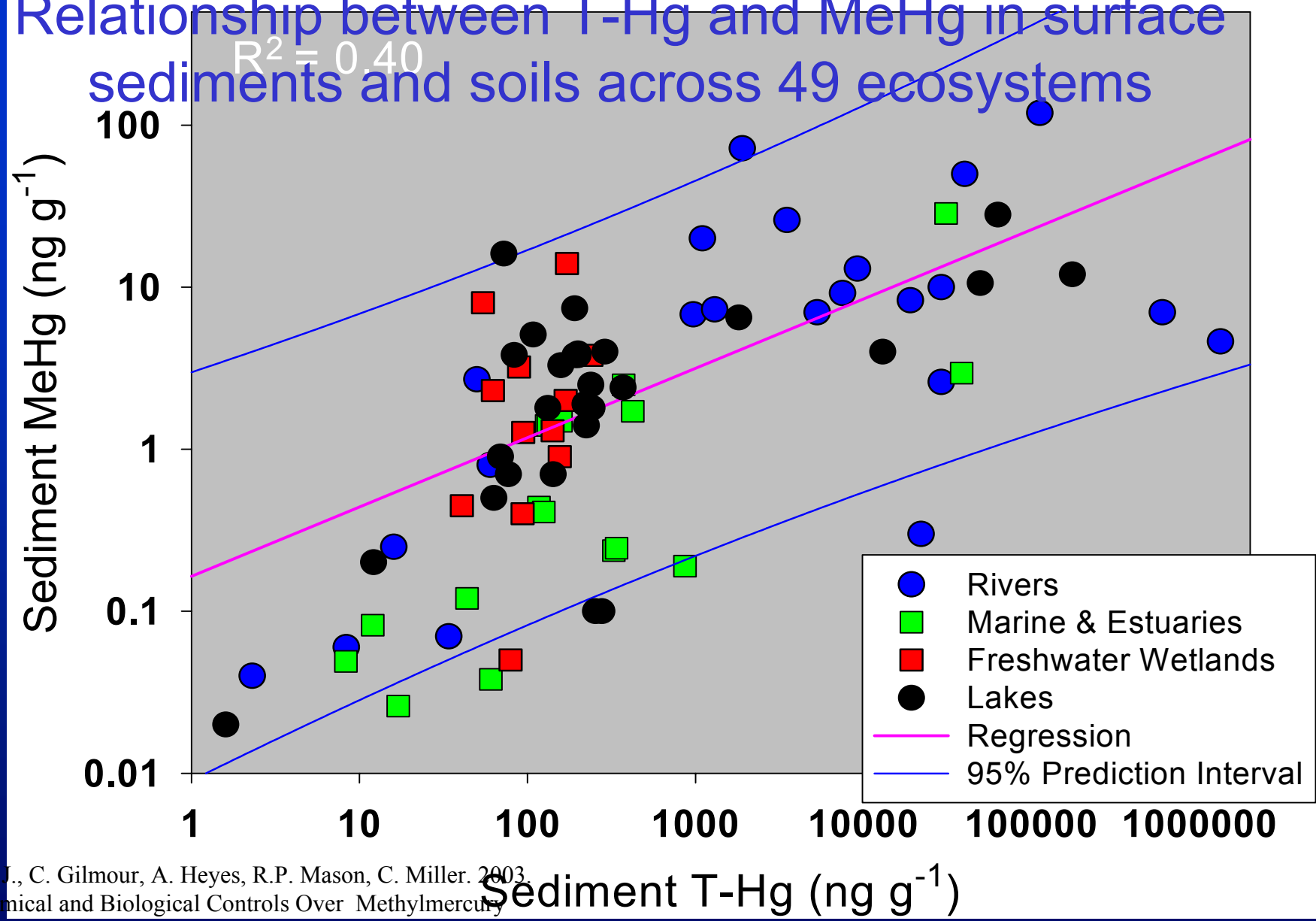
Source: Parks and Hamilton 1987

Many of these lakes have similar atmospheric Hg deposition… Does that mean loading is not a factor?



Source: Ontario Ministry of Environment and Energy data

Relationship between T-Hg and MeHg in surface sediments and soils across 49 ecosystems



Benoit, J., C. Gilmour, A. Heyes, R.P. Mason, C. Miller. 2003. Geochemical and Biological Controls Over Methylmercury Production and Degradation in Aquatic Ecosystems. In: "Biogeochemistry of Environmentally Important Trace Elements", ACS Symposium Series #835, Y. Chai and O.C. Braids, Eds. American Chemical Society, Washington, DC. pp. 262-297.

Methylmercury production varies widely among ecosystems

- There is a significant relationship between Hg and MeHg in sediments across ecosystems implying that reduction in Hg deposition will lessen MeHg production.
- However, other factors contribute substantially to the variability in MeHg production within and among ecosystems.
- Mercury load alone cannot be used to predict MeHg production with much confidence.

Where does Hg methylation occur?

In wetlands:

- Surface sediments/soils
- Periphyton

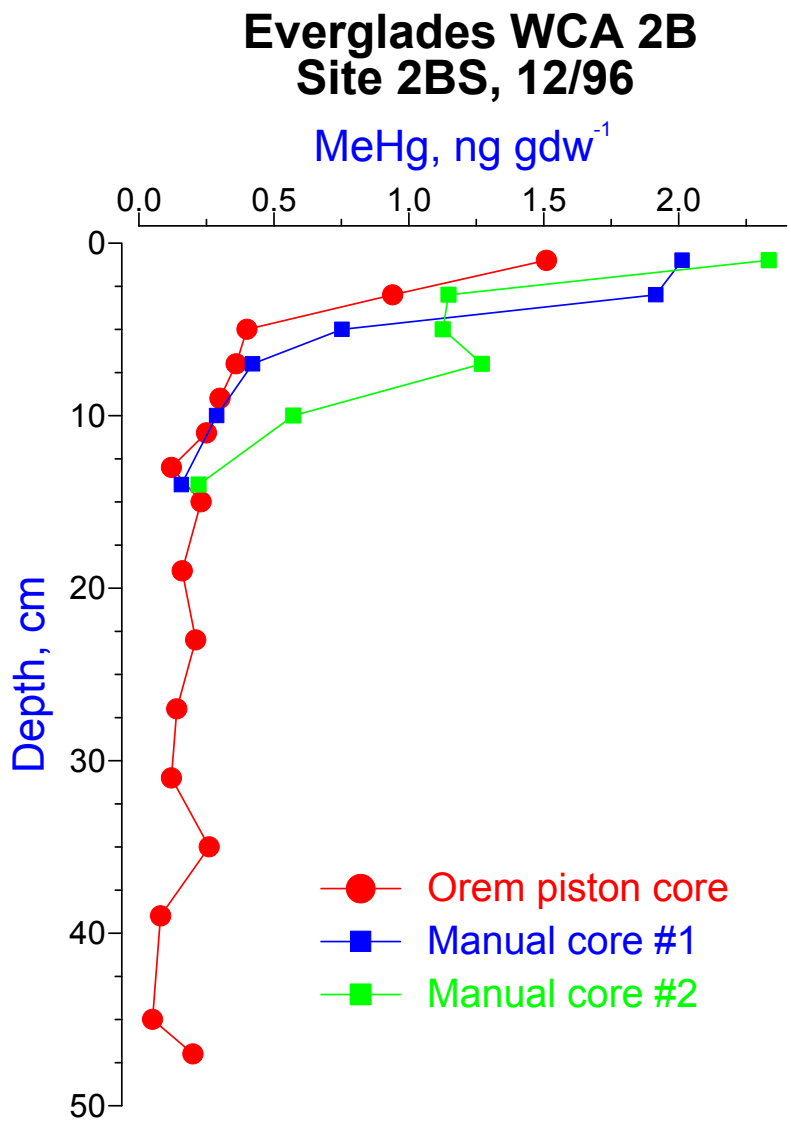
In lakes:

- Surface sediments
- Oxycline

In watersheds:

- Saturated soils

Sewage Treatment Plants



Ecosystems prone to high MeHg:

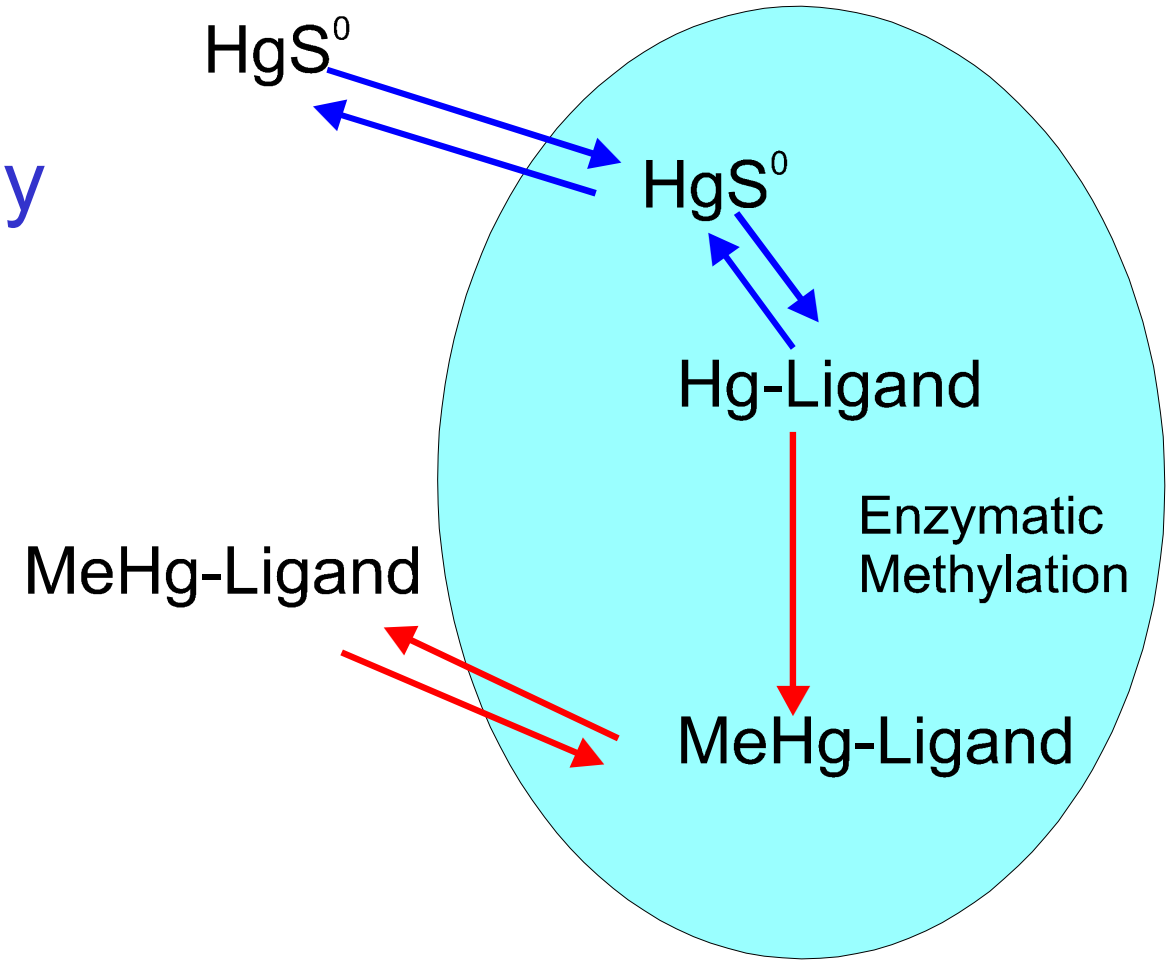
- Freshwater wetlands
- Reservoirs
- Freshwater ecosystems affected by acid deposition
- Ecosystems affected by Hg

Variability in MeHg production among ecosystems is a function of:

- Hg loading
  - Atmospheric
  - Point sources
- Basin geomorphology
  - Wetland area
  - Littoral area
  - Watershed area
- Sulfur loading
  - Acid deposition
  - Agriculture
  - Natural sources
- Controls on microbial activity
  - Temperature
  - Trophic status

- Hg methylation is mediated by sulfate-reducing bacteria
- Methylation occurs inside cells
- Inorganic Hg speciation determines uptake rates by cells

Hg methylation by *Desulfobulbus propionicus*

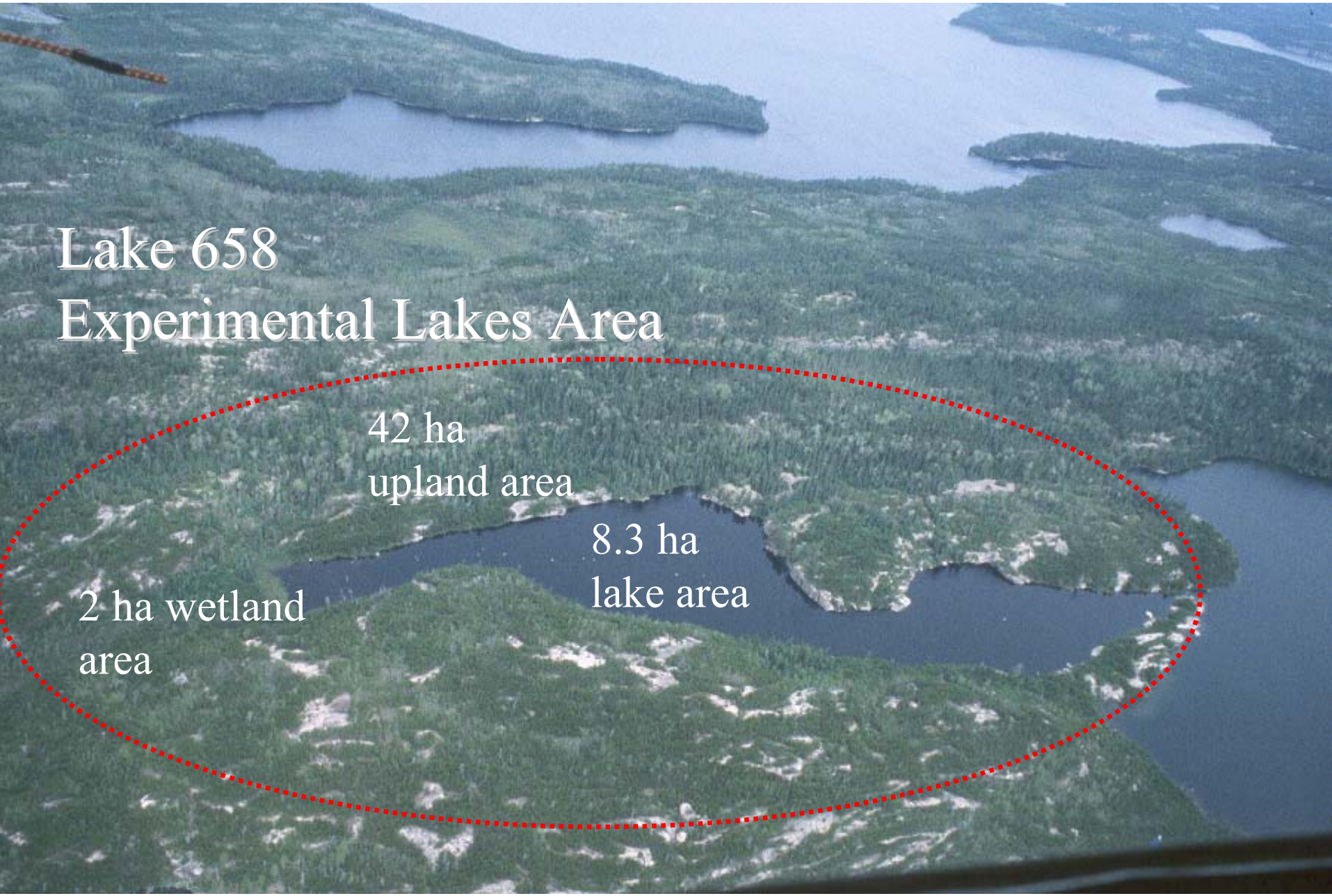


Benoit, J.M., C.C. Gilmour and R.P. Mason. 2001. Aspects of the Bioavailability of Mercury for Methylation in Pure Cultures of *Desulfobulbous proprionicus* (1pr3). In press. Appl. Environ. Microbiol.

What is METAALICUS?

- ***A loading experiment*: Mercury is being added to a lake and its surrounding watershed.**
- **Wet Hg deposition rate is being increased by 4X**
- **Stable Hg(II) isotopes (non-radioactive) are being used**

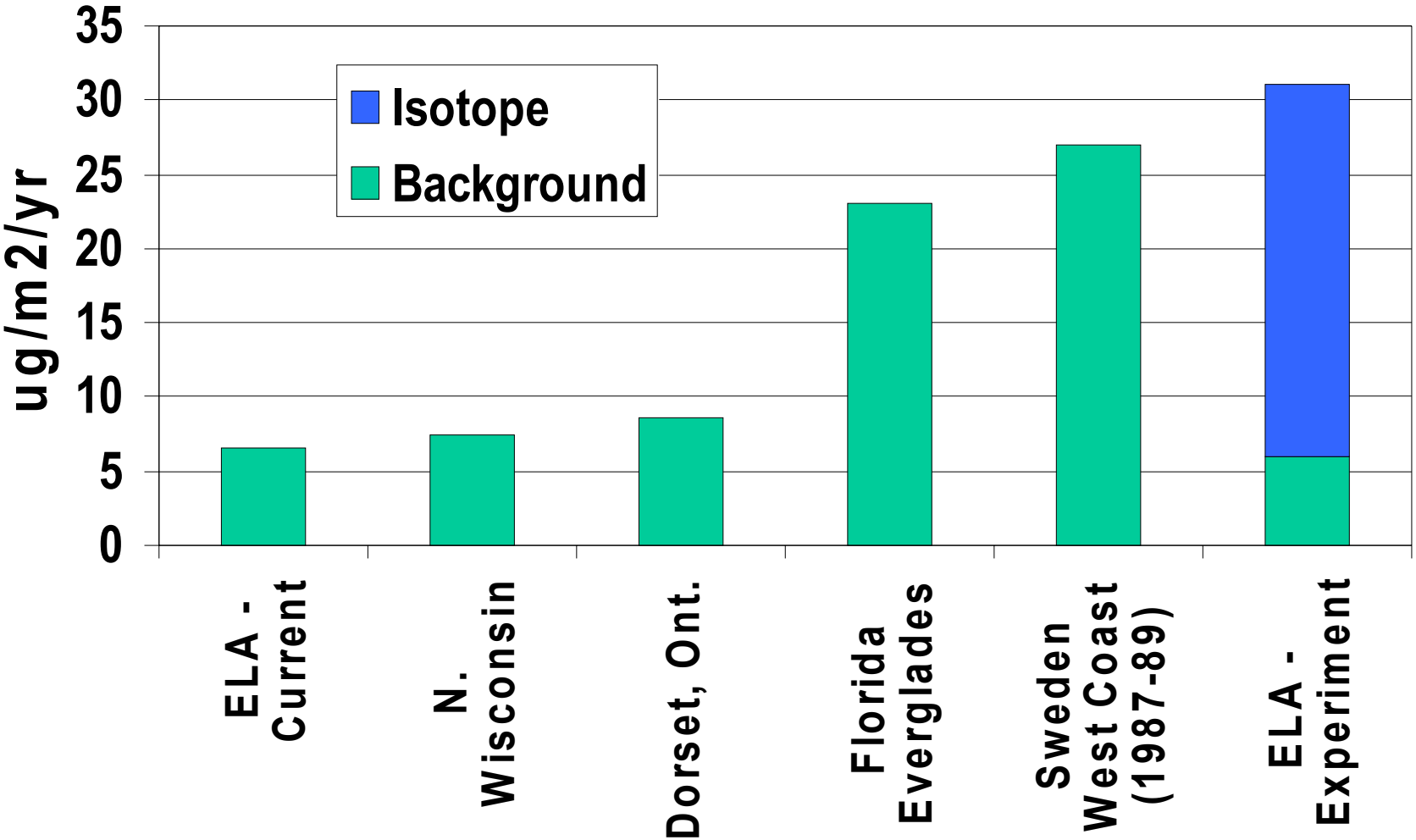
The Experimental Lakes Area Research Facility

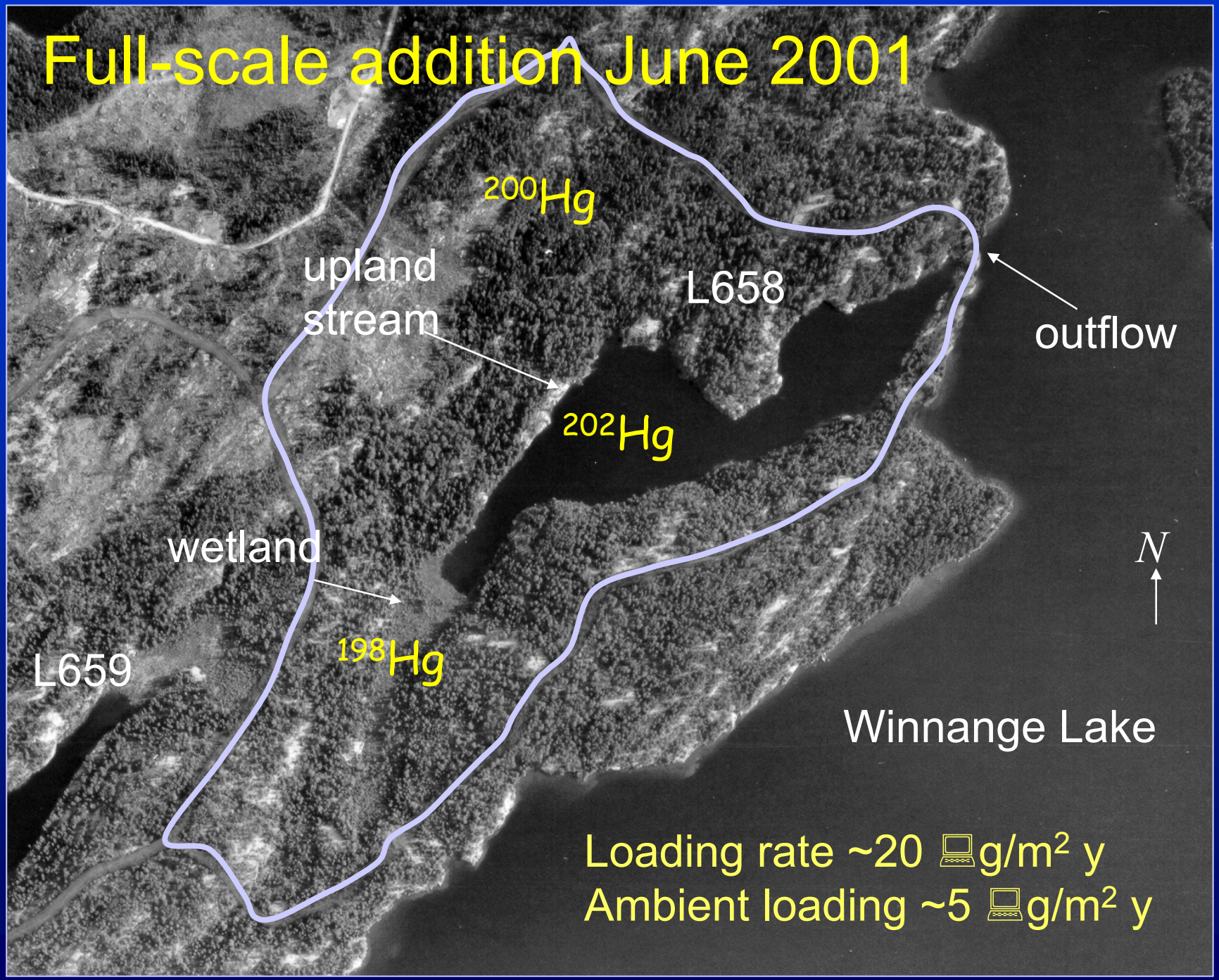

Lake 658
Experimental Lakes Area
42 ha
upland area
8.3 ha
lake area
2 ha wetland
area

METAALICUS Scope

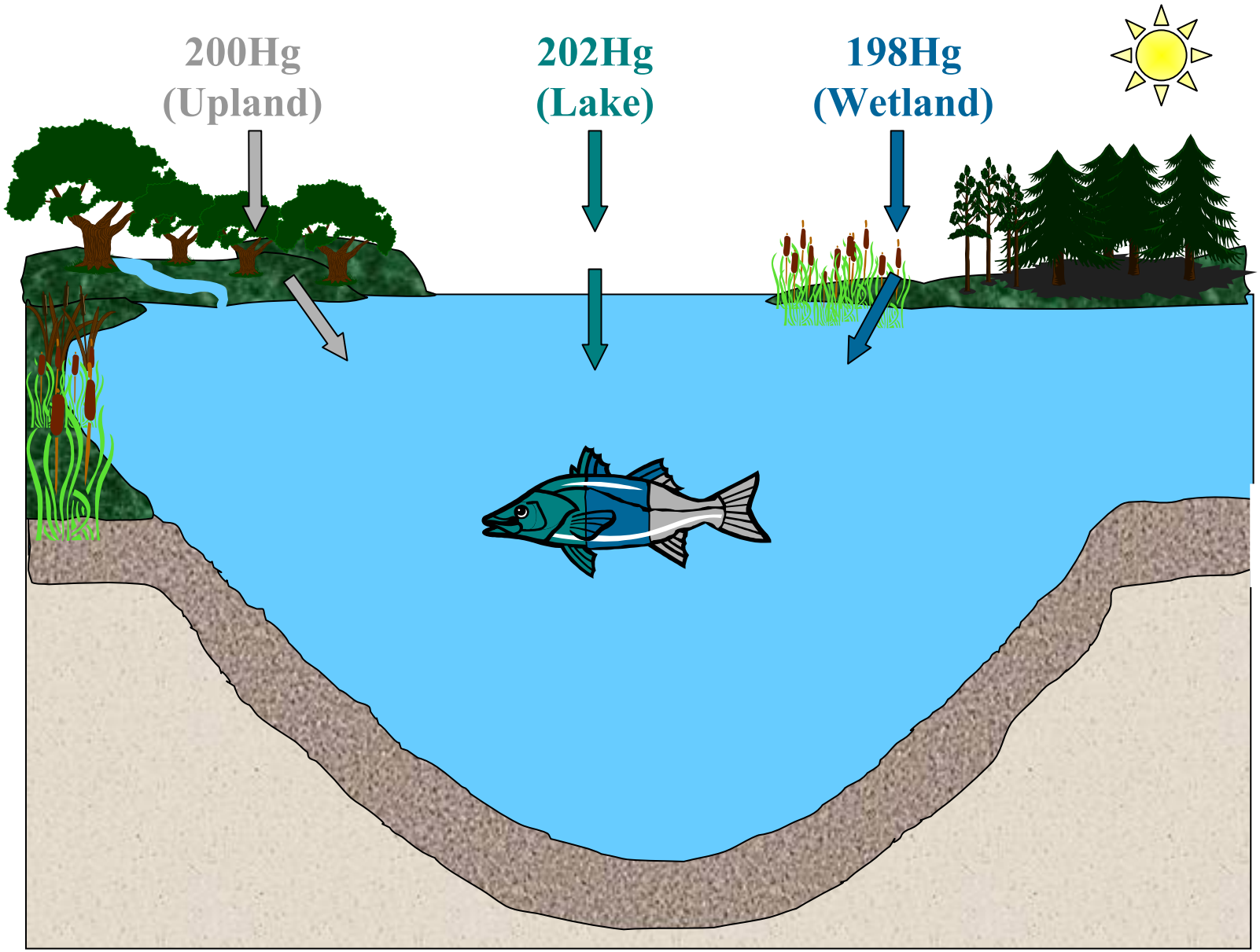
METAALICUS is focusing on the links between Hg loading and fish Hg

How much will wet Hg deposition be increased?

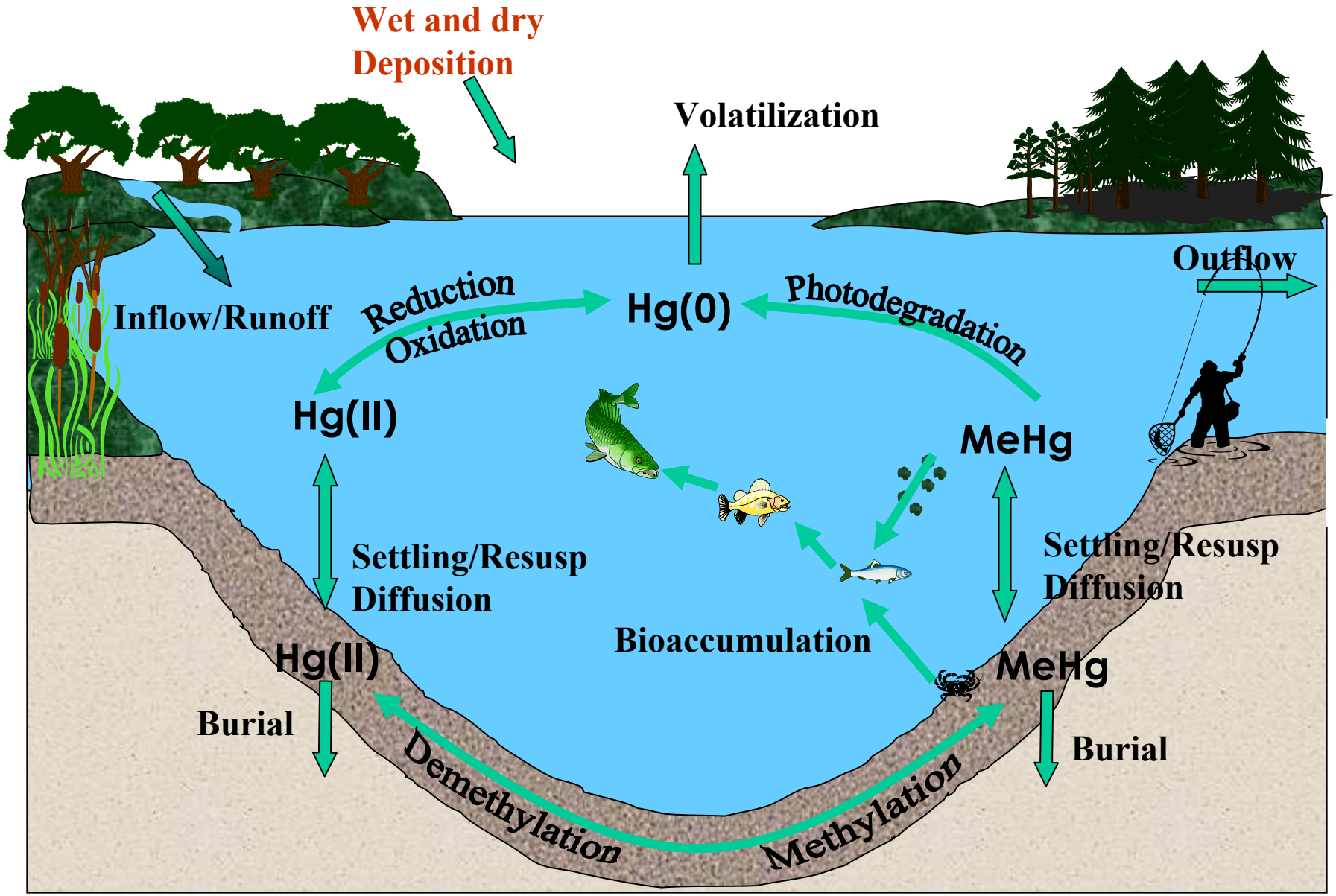



Full-scale addition June 2001
^{200}Hg
upland
stream
L658
outflow
^{202}Hg
wetland
N
L659
^{198}Hg
Winnange Lake
Loading rate ~20 g/m² y
Ambient loading ~5 g/m² y

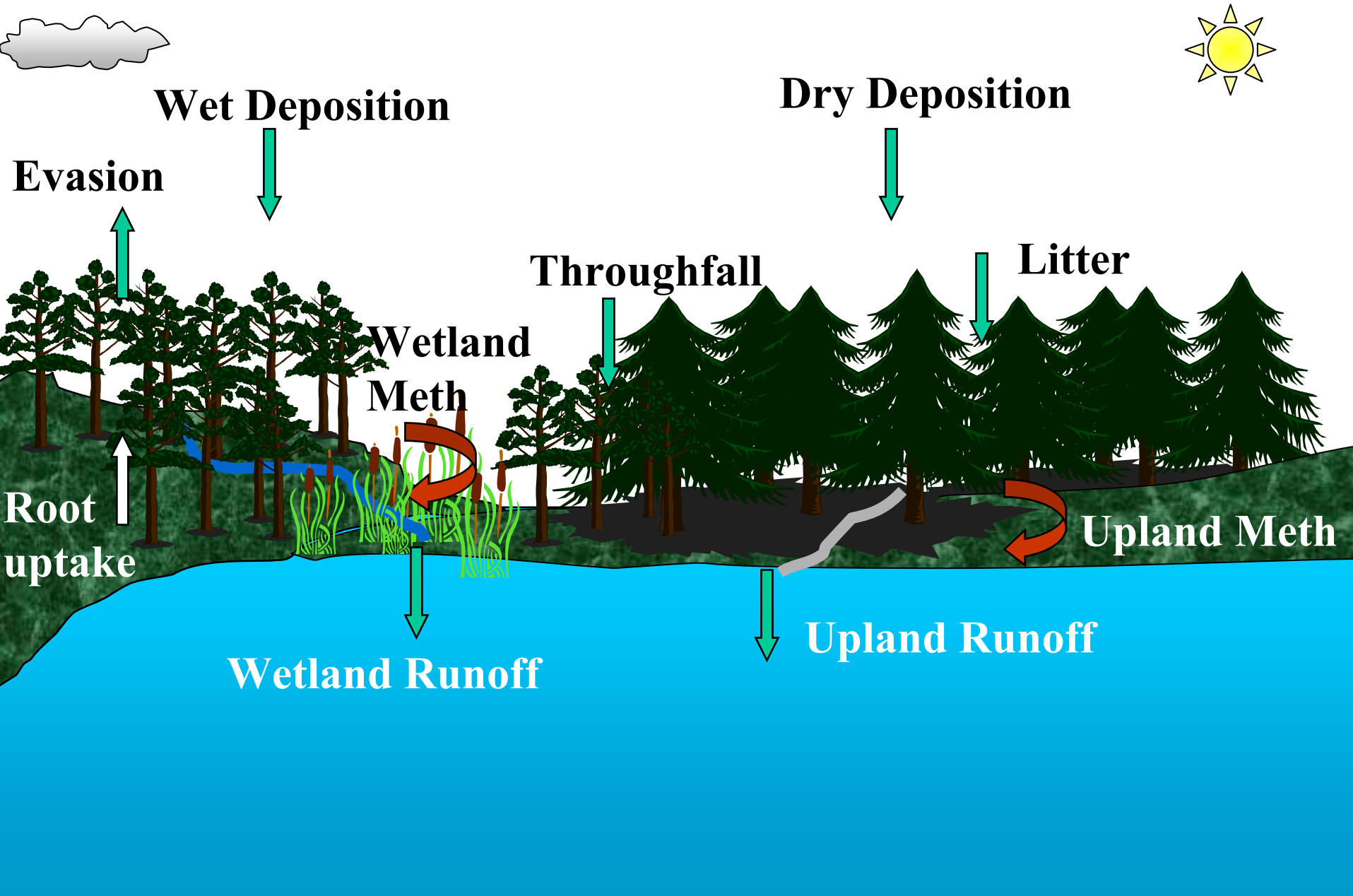
Measure Different Contributions to Fish Hg



METAALICUS is looking at ….



METAALICUS in the watershed



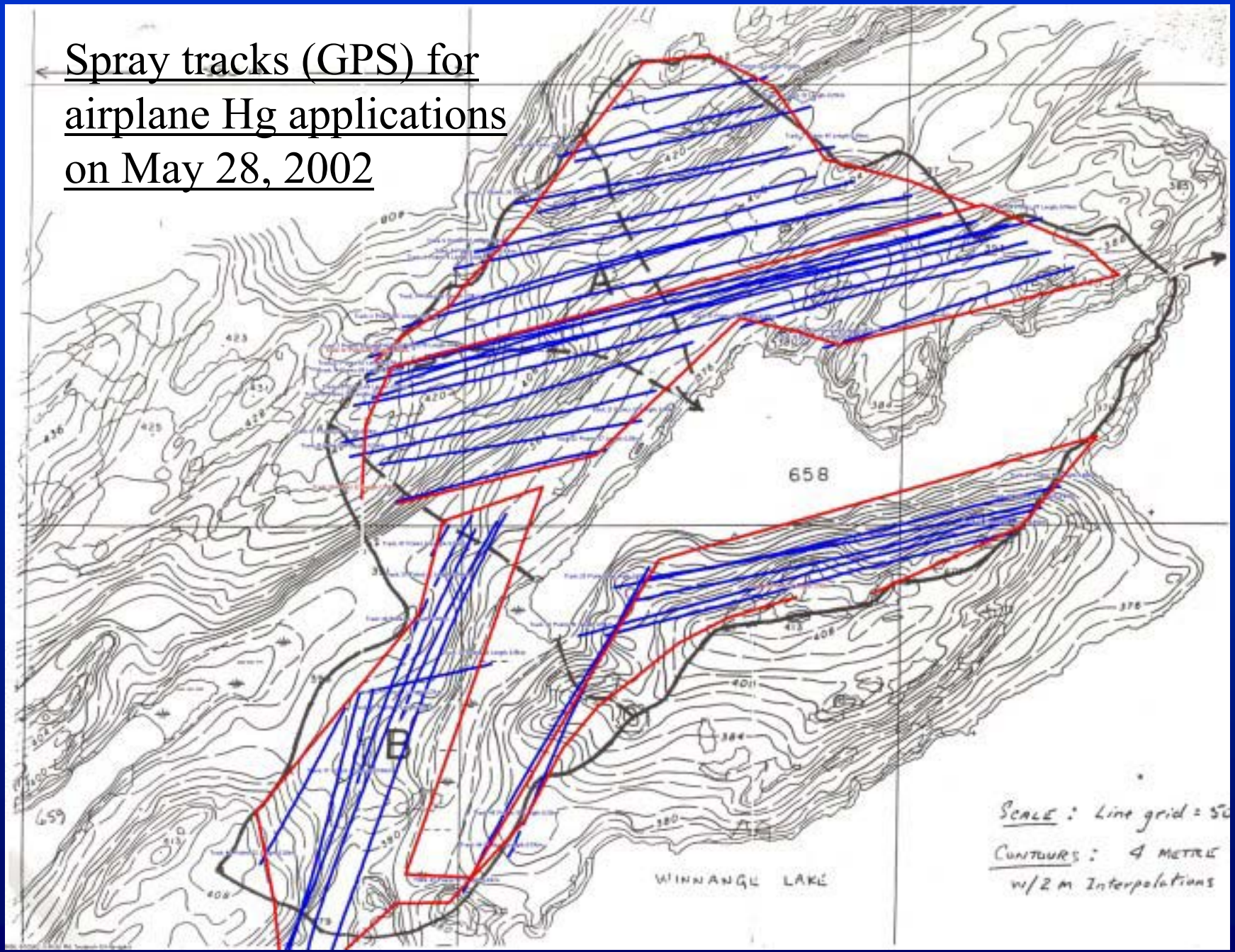
Pilot studies: How much of the added Hg is exported in runoff from an upland catchment?

Mist application to represent light rain or dry deposition:

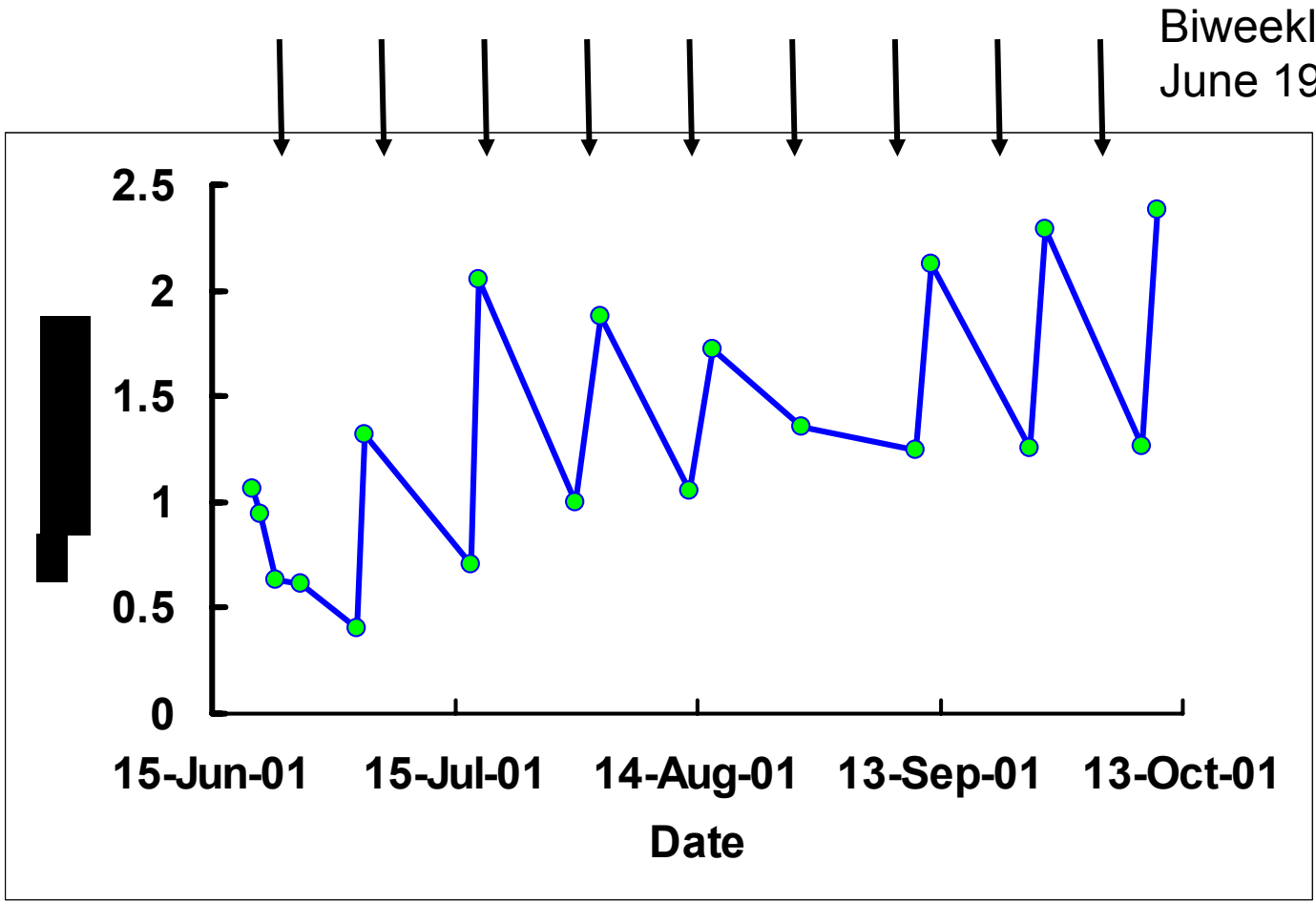
- 0.13% in 1999 (one spike ^{202}Hg)
- 0.06% in 2000 (multiple ^{200}Hg spikes)

Simulated rain application to create runoff flow:

~10-17% (Hg, MeHg) of spike in runoff.

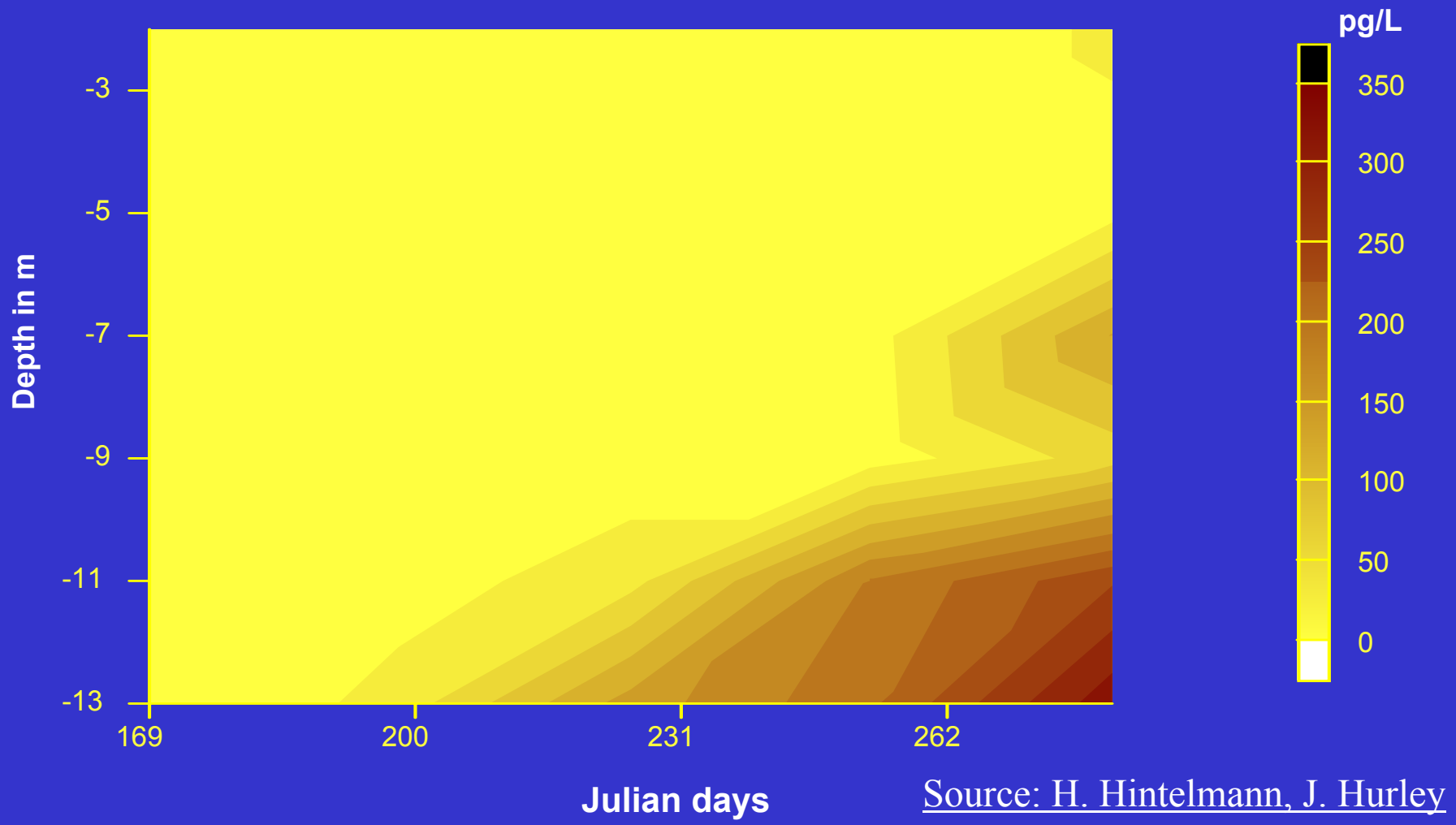

Spray tracks (GPS) for airplane Hg applications on May 28, 2002
658
659
WINNANGU LAKE
SCALE : Line grid = 50
CONTOURS : 4 METRE
w/2 m Interpolations

Lake 658 spikes with ^{202}Hg in 2001



Source: H. Hintelmann

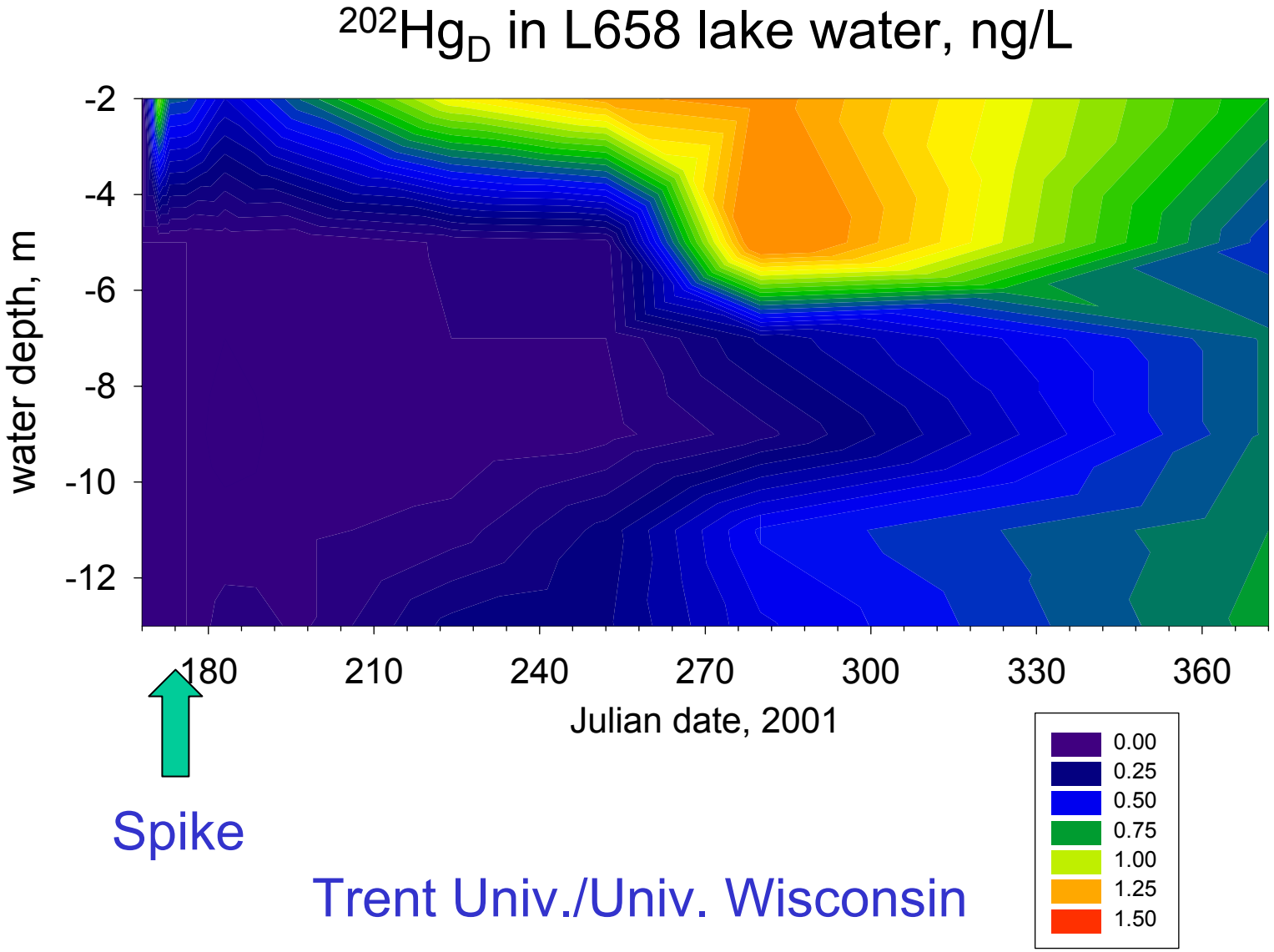
202-MeHg dissolved in Lake 658
June 18 - October 8, 2001



Source: H. Hintelmann, J. Hurley et al.

^{202}Hg in lake water

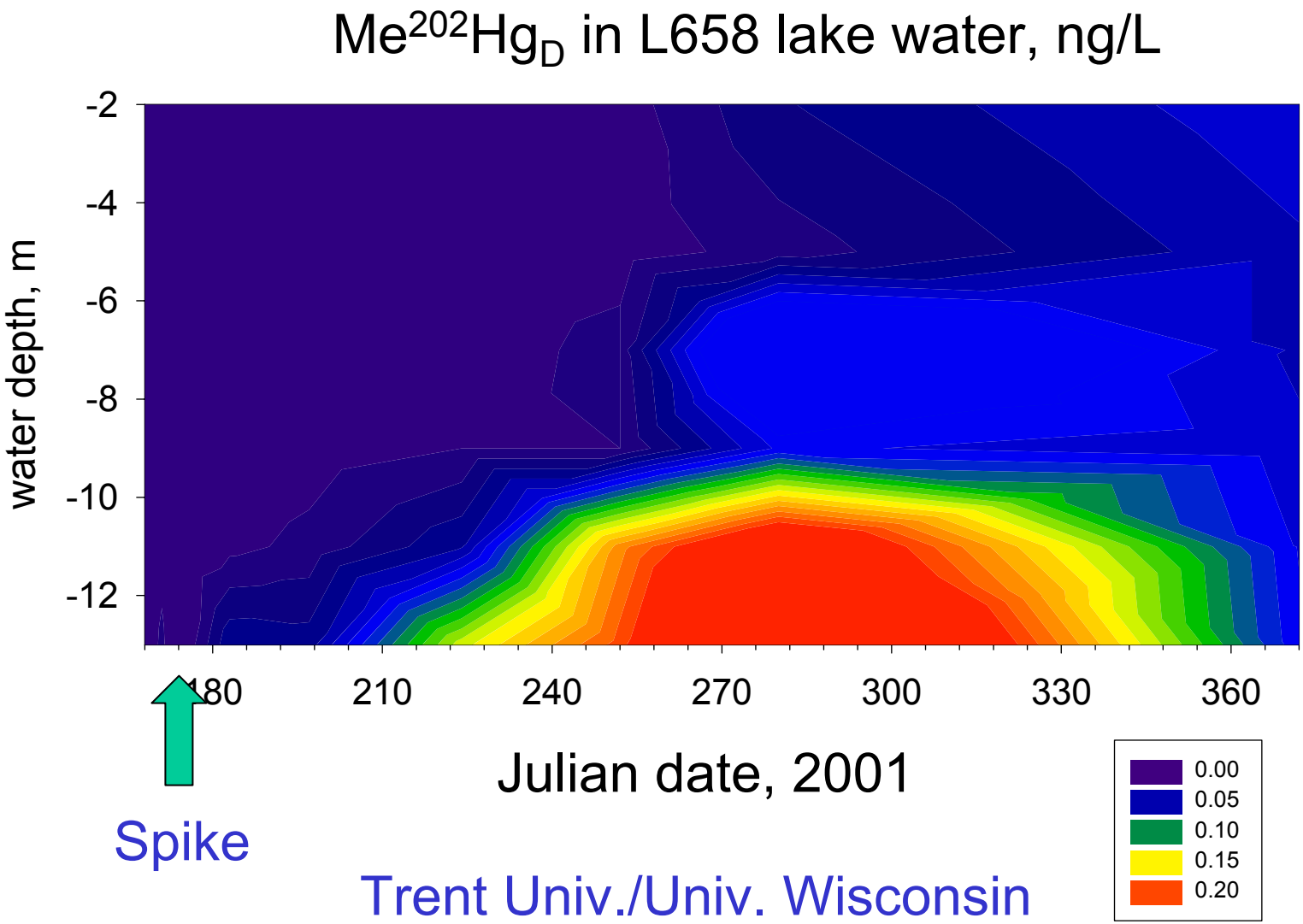
By September, about 30% of Hg in lake water is ^{202}Hg



Trent Univ./Univ. Wisconsin

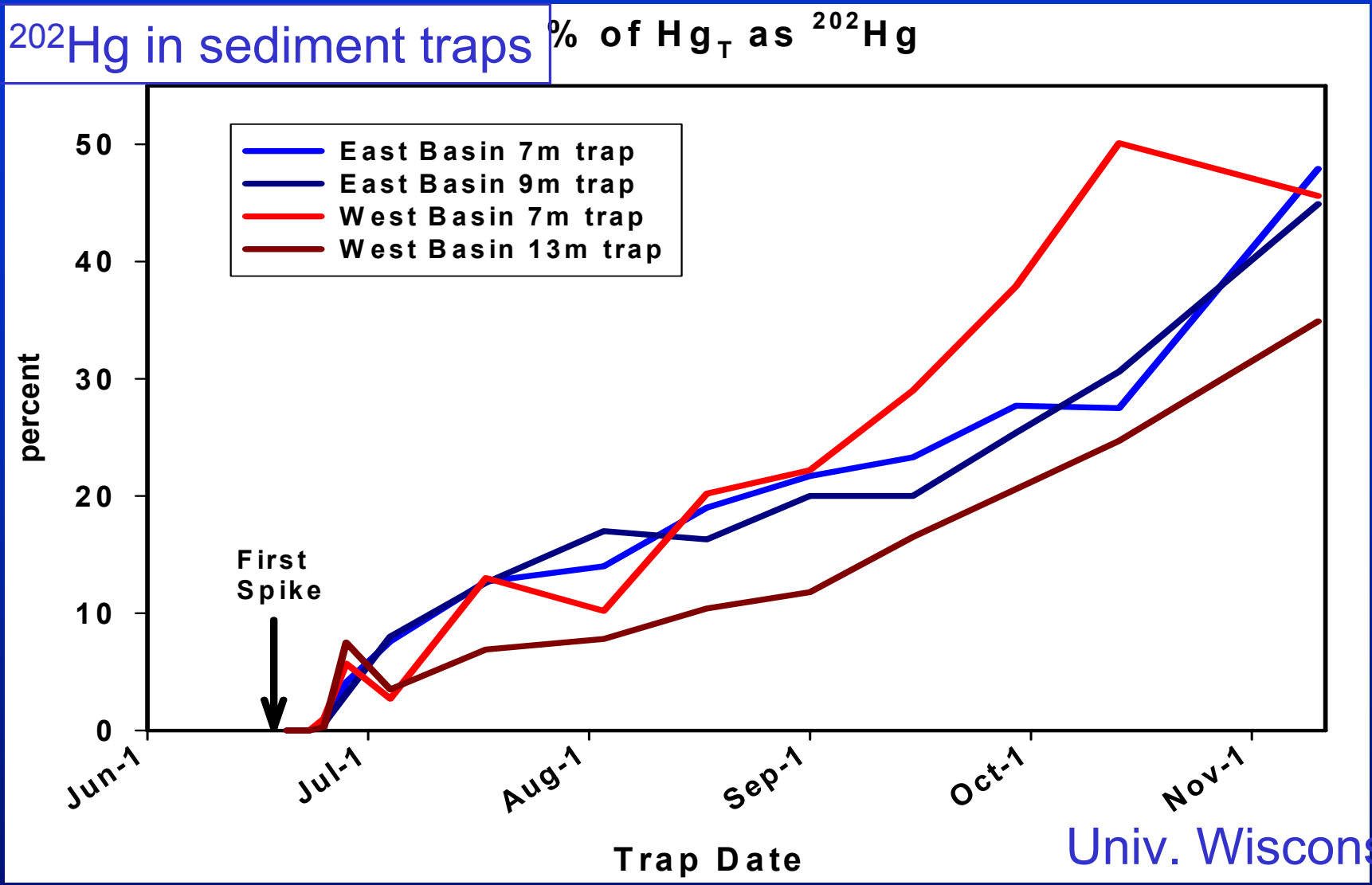
$Me^{202}Hg$ in lake water

By September, about 15% of MeHg in lake water is $Me^{202}Hg$



Trent Univ./Univ. Wisconsin

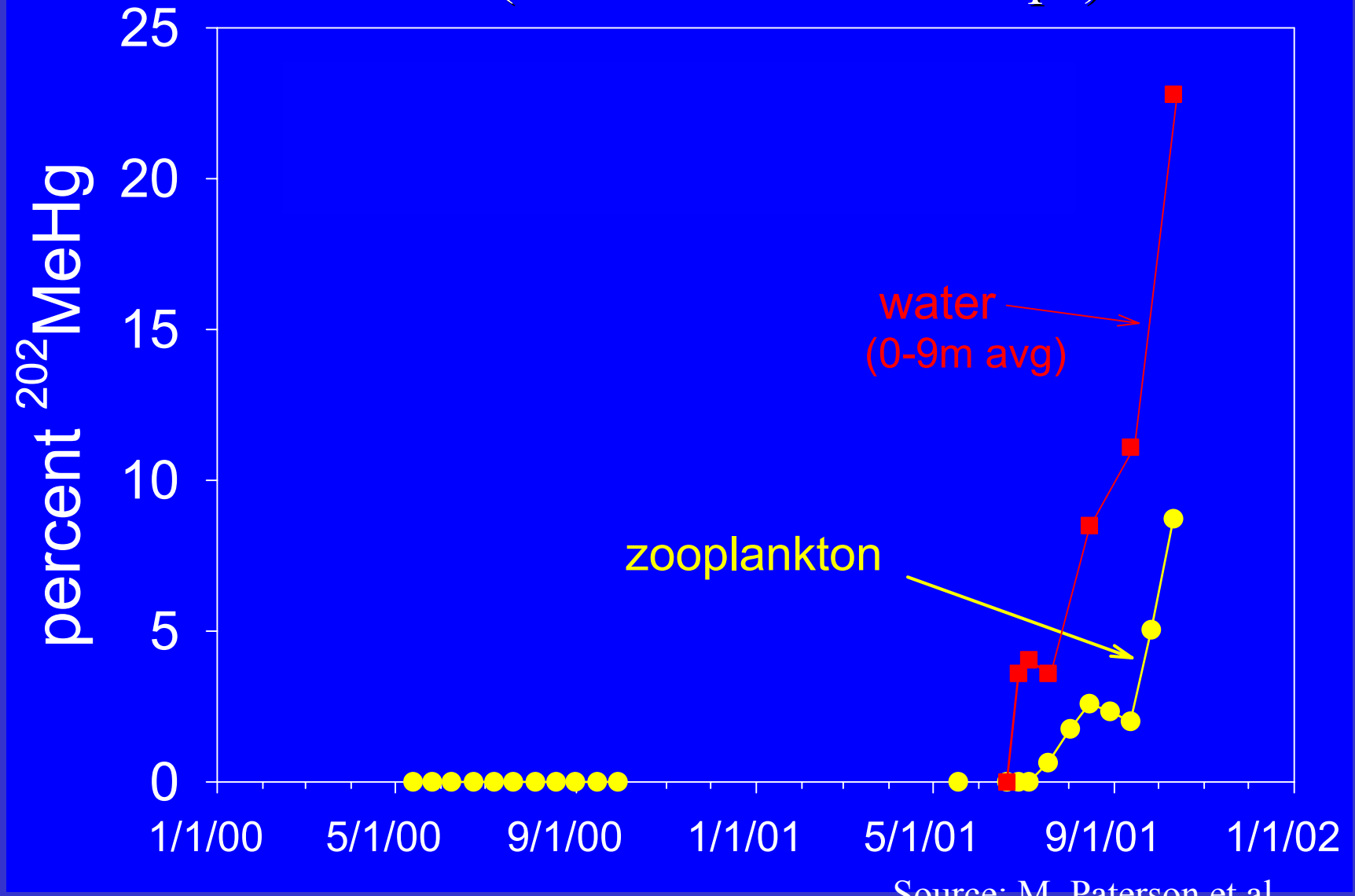
^{202}Hg in sediment traps



Univ. Wisconsin

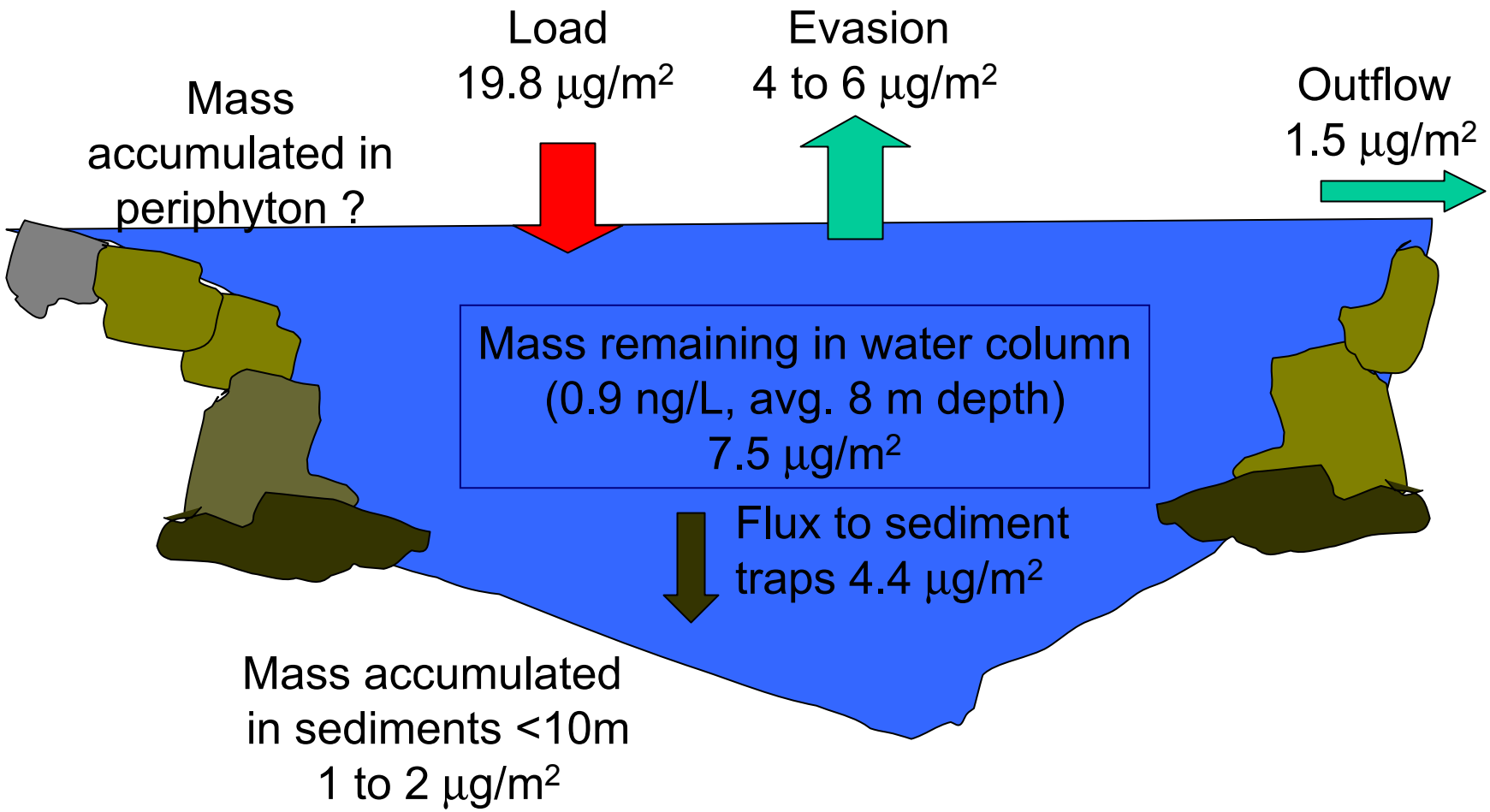
Within *6 days* of spiking, ^{202}Hg began appearing in particles in sediment traps and by late summer, comprised *almost 50%* of all Hg in sinking particles.

Percent of measured MeHg as excess 202MeHg (i.e. due to added isotope)

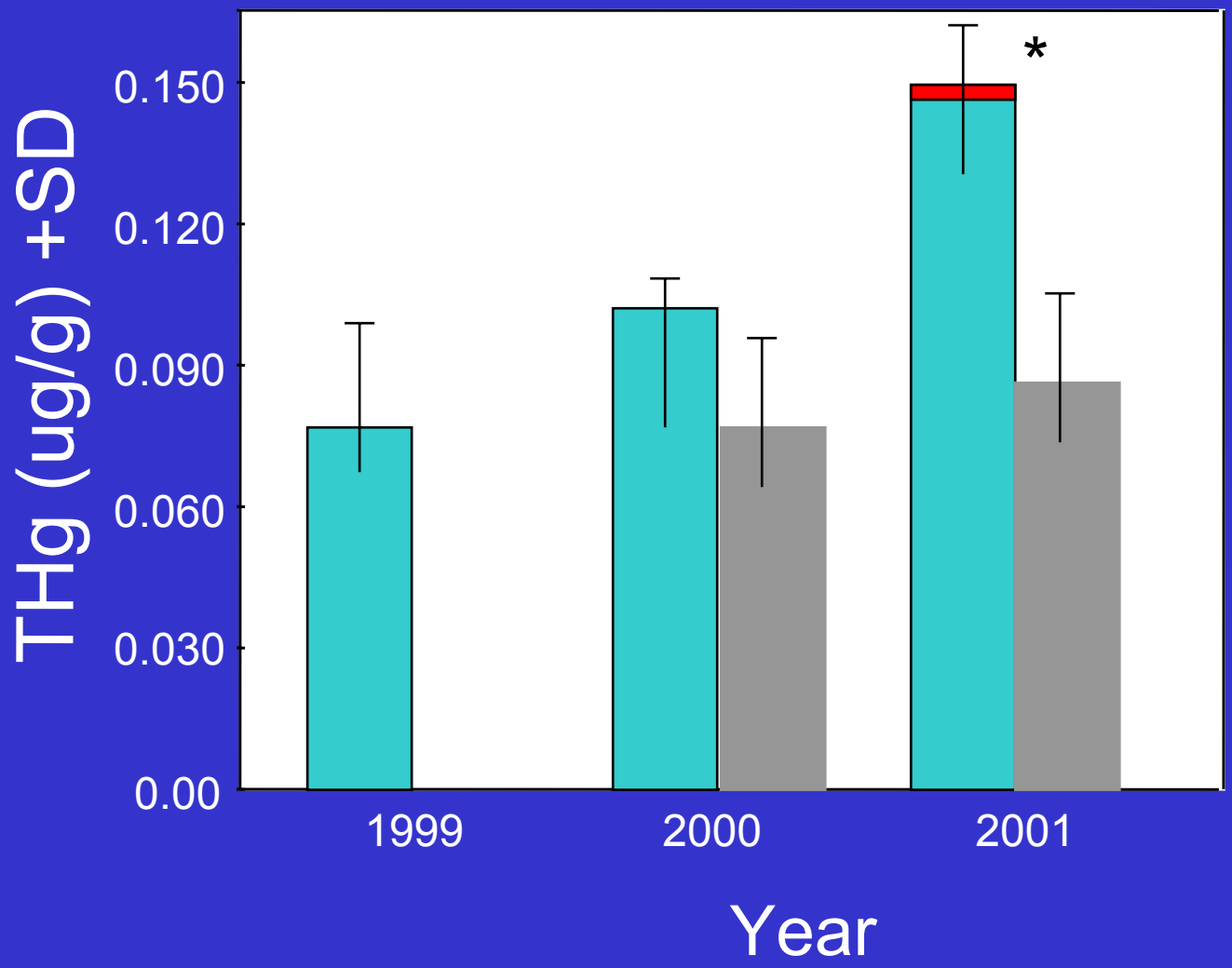


Source: M. Paterson et al.

Preliminary ^{202}Hg Budget for Lake 658 (June – October 2001)



Hg in young of year perch



L658 ambient

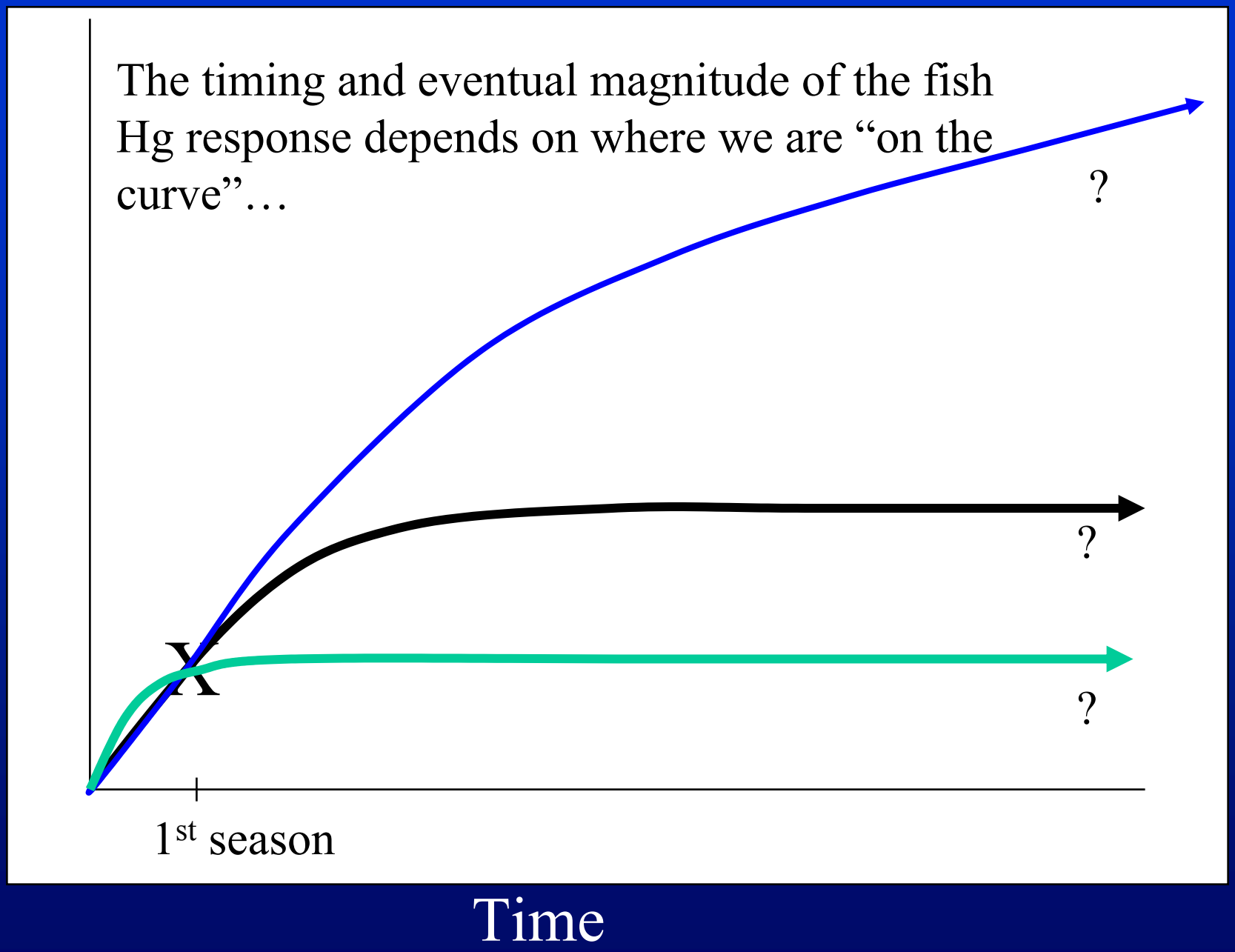
L240 ambient

L658 ^{202}Hg

* at this time only 12 ug/m^2 added to L658

What does it all mean so far?…

1. The conversion from Hg(II) to MeHg of isotope added directly to the lake began quickly (within weeks)
2. Too soon in the experiment to say where the isotopic levels will end up in fish, and when…


The timing and eventual magnitude of the fish Hg response depends on where we are "on the curve"…
?
?
?
X
1st season
Concentration
Time